DOCUMENT RESUME

ED 235 027 SE 043 281

AUTHOR Stead, Keith; Osborne, Roger
TITLE Friction. Learning in Science Project. Working Paper No. 19.
INSTITUTION Waikato Univ., Hamilton (New Zealand).
PUB DATE Sep 80
NOTE 30p.; For related documents, see ED 226 976 and SE 043 265-315. Document contains some marginal legibility.
AVAILABLE FROM University of Waikato, Science Education Research Unit, Hamilton, New Zealand.
PUB TYPE Reports - Evaluative/Feasibility (142) -- Reports - Research/Technical (143)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Cognitive Processes; Comprehension; *Concept Formation; *Curriculum Development; Elementary School Science; Elementary Secondary Education; Interviews; Learning; Motion; Physics; Science Education; *Science Instruction; Scientific Concepts; *Secondary School Science
IDENTIFIERS Friction; *Learning in Science Project; *New Zealand; Science Education Research

ABSTRACT

One area explored in the second (in-depth) phase of the Learning in Science Project was "children's science," defined as views of the world and the meanings for words that children have and bring with them to science lessons. The investigation reported focuses on students' thinking regarding their views on friction. Students (N=47) were individually interviewed using a variation of the interview-about-instances procedure. Ten cards (included in an appendix), each illustrating a single situation where friction may or may not occur, were shown to students to elicit their views. These views are presented and discussed under the following headings: friction and force; friction and reaction; friction and movement; friction and energy; friction and solids, liquids, and gases; friction and electricity; friction and particles; and friction and the world in which we live. Additional views presented and discussed focus on friction as it relates to: children's everyday language; self-centered and human-centered viewpoints; animistic views; reified views; and the non-existence of non-observables. General conclusions (such as a close association between friction and rubbing) and questions for further study are included. Additional materials (in appendices) include a scientist's explanation of information on the interview cards, student views on how rubbing makes electricity, and survey questions used to gain indications of the prevalence of selected ideas related to friction. (JN)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED2350027

LEARNING IN SCIENCE PROJECT

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

✓ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

FRICTION

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

Roger Osborne

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

University of Waikato
Hamilton, N. Z.

SE043281

WORKING PAPER No. 19

In our view successful science teaching requires an appreciation not only of the scientists' view of the world, but also an appreciation of the language, the beliefs and the expectations which children bring with them to science classes. This working paper has developed from a study carried out in the in-depth phase of the Learning in Science Project and is one of a series of papers which explores aspects of Children's Science (see Working Paper No. 14). It is our hope that these papers portray children's views of the world and meanings for words in a way which will be useful to teachers and to curriculum developers.

In the action-research phase of the project it is our intention to attempt to build practical and useful teaching strategies based on the findings of the in-depth phase of the project. For this reason we are actively seeking comments on the findings we have detailed, and seeking information on the variety of ways teachers develop ideas associated with the topic under focus in this paper.

We would be grateful if comment and/or information could be forwarded to

The Learning in Science Project,
University of Waikato,
Private Bag,
HAMILTON.

FRICTION

A working paper of the Learning in Science Project

Keith Stead and Roger Osborne

September 1980

INTRODUCTION

One of the topics we have studied in depth as part of the Learning in Science Project is the topic of FORCE (Working Paper No. 16). Out of that work it became clear to us that certain ideas closely associated with the idea of FORCE should also be investigated, namely FRICTION and GRAVITY. This paper details investigations related to the first of these two words.[1]

The information detailed in this paper was obtained using a variation of the interview-about-instances method used to investigate FORCE. A deck of 10 cards (see Appendix 1) was used in the interviews to provide a focus to discussion about the idea FRICTION, and allowed questions to be asked in a semi-structured way. Each card depicted a single situation where friction may, or may not, occur. Unlike previous studies in this series, students were asked at the outset of the interview,[2]

> I "In your meaning of the word friction, what is friction? Where do we find it? What does it do?"

The order of the stimulus cards was also varied from interview to interview.

A total of 47 students ranging from Form 1 to Form 6 (9 x F1, 9 x F2, 12 x F3, 9 x F4, 4 x F5, 4 x F6)[3] from five different schools were each interviewed individually. Interviews were audio-taped and the tapes were later transcribed and analyzed.

In this paper responses to the initial questions, and subsequent discussion focussing on the cards, are summarized. In the first section of the paper various

---

[1] GRAVITY will be considered in a subsequent paper.

[2] After endeavouring to establish an informal, relaxed atmosphere and explaining the general nature of inquiry to the student.

[3] The F5 students were taking science for S.C. and the F6 students were all taking U.E. Physics.

aspects of students' views on friction are considered. The subsequent section deals with certain aspects of children's views about FRICTION which can be related to common findings from our earlier investigations, e.g. Working Paper No. 16 on Force.

Following the interview work and the analysis of the results a survey was developed to investigate the prevalence of some of the views identified through the interview work. In developing the survey questions further interviews identified why children chose particular responses. These later interviews showed that the reasons why students choose a particular distractor are not always the ones we might expect.[4] However, with that qualification in mind, the results detailed in Appendix 3, and referred to where appropriate in the body of the paper, do provide further information on students' views.

ASPECTS OF STUDENTS' VIEWS ON FRICTION

Perhaps one of the main features of the interviews was that the majority of those interviewed closely associated friction with rubbing, particularly the rubbing of two solid surfaces. Approximately 50% of the F2-6 students explicitly mentioned 'rubbing'.[5] Unfortunately, the everyday association of rubbing with movement, wear, heat, pressure between surfaces, and so on leads to a number of non-scientific views about friction as we shall see.

(a) Friction and Force

Some students (1 x F2, 1 x F3, 3 x F5, 2 x F6)[6] had a clear appreciation of friction as a force and could make that explicit.

> "It's like a force ... like when two things get rubbed, the force, sort of, that they do is friction". (F2, girl)

> "Friction is about two forces opposing each other". (F5, girl)

> "It's a force between two objects and friction acts in the opposite direction". (F6, girl)

Other students (3 x F2, 2 x F3, 1 x F5, 1 x F6) basically viewed friction as a force but had greater difficulty stating this explicitly.

---

[4] See Appendix 3(a) p.20, Footnote 9.

[5] The F1 students that we interviewed tended to have no meaning at all for the word friction and their views will not be examined in depth in this paper.

[6] Numbers detailed in this way should be interpreted as merely giving in indication of the prevalence of a particular viewpoint.

"It's steadiness ... grip ... not being able to slide as easily ... it's sort of a kind of force". (F2, boy)

"I think it is a force ... I am not sure". (F4, boy)

"(It's) a resistance between two surfaces ... It's sort of undefinable". (F6, boy)

Finally, others (2 x F2, 2 x F3, 1 x F4) seemed to consider it a kind of force, as determined by their responses to the cards, but were unable to state this explicitly.

Some had the idea of force but considered the force to be magnetic or even gravitational. For example,

K "What is friction?"

M "Oh, it's just a magnetic force, sort of thing, which is by rubbing things, or like the car is skidding and picks up a force, a magnetic force, on to the things it's sliding on, and like a magnet, it just picks it up, sort of thing". (F4, boy)

K (card No. 7: boy on slide) "... tell me about that one, Kim".

Ki "Oh it (the friction) makes him slide down so he lands - makes him slide down the slide".

K "Sure, so where abouts is the friction exactly?"

Ki "On the ground".

K "It's on the ground? So, if it's on the ground, how is it getting to him ?"

Ki "Oh, it just pulls down like a magnet".

and later

K "Is there anything to do with friction there, do you think, as they (skydivers) fall?"

Ki "Yeah, it's pulling them back down towards the earth".

(F3, boy)

(b) Friction and Reaction

In our view, one of the difficulties in teaching senior physics is establishing clearly in students' minds the difference between reaction forces and frictional forces. It is not surprising, therefore, to find students who associated friction with what physicists would call a reaction force. (3 x F2, 3 x F3, 2 x F4, 1 x F5, 1 x F6).

K "Okay, let's take this boy coming down the slide (card 7), is there any friction there?"

J "No".

K "Hmm, what about when he hits the bottom?"

J "Yeah".

K "So there would be friction when he hits the bottom - would there be much friction?"

J "No".

K "Why do you say that?"

J "Cos he's sort of coming to a soft landing".

K "He comes to a gradual halt?"

J "Yeah".

K "There's only friction when there's a heavy jolt at the end?"

J "Yeah".

K "Okay, so if he stood on the top here and fell off (yeah) there'd be a lot of friction when he hit the ground?"

J "Yeah".

This girl has a very clear non-scientific concept of friction, as was apparent when she was asked for her definition at the end of the session.

"It's when something hits hard together. You get some friction that's soft but not much, and you have hard, ordinary friction". (F4, girl)

Others made similar responses,

"(there is friction) only when (the parachutist) hits the ground". (F3, boy)

D "Um, like we've got friction now. I'm sitting on a chair and ..."

K "Well, as you're sitting still on that chair, have you got any friction on you anywhere?"

D "Yeah, I'm opposed to the floor". (F5, girl)

K "What is it that makes a lot of friction under, or on, the banana peel?"

D "The pressure".

K "The pressure? It could be the same pressure under the other foot".

D "Then there's probably friction under that one".

K "I see. So, what exactly is pressure?"

D "It's a force".

K "It's a force? Is friction a force?"

D "Ah - I don't know, it could be".

K "Mmmm, so what's a force?"

D "A pressure". (F2, boy)

Some quantitative indication of the prevalence of the confusion between reaction and friction forces is provided in Appendix 3(a).

(c) Friction and Movement

A not unusual view held by all age groups (4 x F2, 5 x F3, 6 x F4, 1 x F5, 1 x F6) was that friction was associated with movement. If there was no movement then there was no friction.

K (card No. 7) "We've got a boy coming down a slide here, Reece, any friction in that scene?"

R "Yes".

K "Where abouts?"

R "On - down the back of his legs and where he's rubbing against the steel or wood on the slide, and on his hands where he's holding on there".

K "Okay, say he holds on very hard when he gets half-way down and he stops himself, what's that doing to the friction? Is that increasing it or decreasing it?"

R "Increasing it".

K "And what say he stops - actually stops moving - what about the friction then?"

R "It would decrease it - yeah, decrease it".

K "Would there be any friction when he stopped?" When he's holding on very tight?"

R "No". (F3, boy; also 4 x F4)

K (card No. 5) "... So, there's friction under the foot that slipped?"

J "Yeah".

K "What about the other that's standing firm? Is there friction there?"

J "No, because it hasn't actually moved or anything". (F4, girl; also 2 x F4, F2)

Friction was almost the movement itself to a few students,

K "What is friction all about?"

L "Ah, friction is something like movement".

K "Mmm, and if there's no movement, there's no friction? Is that right?"

L "Yes". (F2, boy)

M "(Friction is) how fast things do ... rub against each other. Like sandpaper rubbing against a piece of wood causes friction".

K "And exactly what is friction?"

M "How fast you are going".

K "It's to do with speed?"

M "Yes". (F3, boy)

"It's a couple of forces rubbing against each other ... it's like a push or a pull ... like getting a grip ... gripping on to something and sort of two things pushing against each other and the friction's the movement between them". (F4, boy)

Sometimes confusion occurred when distances were explicitly involved; three students had the impression that an object sliding some distance was subjected to greater friction than if it slid only a short way. With card No. 9 students were told two identical objects were pushed across a table and one (Y) went further than the other (X).

M "There could be more friction under the (Y) side of the table".

K "Mmm ... so what does that do, if there's more friction under Y?"

M "Makes it slide further". (F3, girl)

and,

K (card No. 1) "... if that car is sliding on, say, ice, is there much friction, or is there no friction?"

J "Be quite a bit of friction".

K "Quite a bit of friction? What say it's sliding on tarseal? Would there be more friction or less?"

J "Less". (F4, girl; F3, girl)

In Appendix 3(b), the prevalence of answer 'b' in Q.3, answer 'a' in Q.4 and Q.5, give a very strong indication that the association of friction with movement is very widespread.

(d) Friction and Energy

Friction was closely identified with energy, particularly heat energy, by some students (1 x F2, 1 x F3, 3 x F4, 1 x F5). If friction is associated with rubbing and movement this is not particularly surprising.

S "When two things rub together it causes friction".

I "... what exactly is the friction?"

S "Energy"

and later,

"It's the energy that comes from something moving". (F4, boy)

Friction was very occasionally used interchangeably with the word heat.

"The wheels, there's friction; as it moves it creates friction". (F4, girl)

On the other hand it was possible to find one or two young students who differentiated between movement, friction, and heat. The following student considered there was a friction force on someone stationary on the slide. Later he initimated that friction creates heat.

K "So friction somehow makes heat?"

A "Yeah, it can".

K "It can, but not always? (no) Can you give me an example of when it might not make heat?"

A "Um, when you go down a slide you don't make heat if you stop yourself on the slide".

(F2, girl)

In Appendix 3(c) the prevalence of answer b gives an indication of the close association in many students' minds between energy and friction.

(e) Friction and Solids, Liquids and Gases

Twelve students considered that friction was associated with the rubbing together of only solid objects (3 x F2, 4 x F3, 4 x F4, 1 x F6) while others considered friction could occur with liquids but not in air. (3 x F2, 1 x F3, 3 x F4, 2 x F5, 1 x F6)

K "These skydivers are falling through space, through the air, down towards the ground, is there friction there?"

G "No".

K "No friction? What about when they open their parachutes? Does that change the situation?"

G "Um, I don't think so".

K "Still no friction".

G "No".

(F4, girl, also F4, 2 x F5, F6)

This same fourth form student, a little later, states "You can't really have friction between something like water and air, and that sort of stuff".

Sometimes, students found that they needed to reconsider their views in the interview as a consequence of the instances they were shown.

K "If we went back to that card with the lad swimming in water, the question of friction in water?"

C "Um - I'm not sure really. The water - oh - the water isn't actually a - the water isn't - um - it's only - the water isn't actually one surface, is it? Yeah, one solid surface - where the body is - um - I'm not very sure about that one.

(F6, girl)

This student was obviously wrestling with the contradiction that, although there was present an opposing force on the swimmer as he moved through the water, the water itself is not solid and, for this student, friction occurred only between two solid objects. So, what was that opposing force? Could it be friction? Surely not!?

In Appendix 3(d) a quantitative survey indicates the prevalence of the views considered in this section.

(f) Friction and electricity

A number of students were familiar with electrostatic charging by rubbing (card 4); hence, there was an association between friction and electricity. While most of these students tended to state that friction causes electricity,[7] one or two students identified friction with electricity.

K "What about when you're swimming in water? Is there friction then?"

R "... No, I don't think there is".

K "Why not? You could be right".

R "Friction is electricity, you know, a current, and you'd feel the shocks, swimming through the water, because the currents go through the water and electrocute".

(F4, boy)

K "What is friction?"

R "Oh, it's caused by two elements rubbing together and it forms electricity - oh pull together - force.

and later,

"It's when something rubs against something else and it moves molecules around and it makes it hotter ... and ... it's ... if one of them loses molecules and it rubs into the other one, so it tries to get it back and the friction in between pulls them together". (F3, boy)

---

[7] Some of the views students had on how friction causes electricity are elaborated in Appendix 2.

In Appendix 3(e) the identification of friction with electricity is investigated more quantitatively.

(g) Friction and particles

None of the students interviewed had any particulate model remotely approximating a scientific view of frictional forces. This is perhaps not surprising as our present syllabuses do not consider such aspects of friction. Nine students however (1 x F3, 3 x F4, 1 x F5, 4 x F6) introduced comments about atoms and molecules into the interview discussion, albeit obliquely, e.g. "heat affects molecular motion", "electricity is a flow of tiny particles". No one was more specific about the molecular aspects of friction than the following F4 boy.

K "Let's take this one (card 8) - a kid swimming in water - is there friction in the water as we swim?"

S "Yeah, I think so, as all the molecules move around as you disturb the water and the particles and all that ... speeds up".

K "What speeds up? The actual friction speeds up?"

S "All the stuff in the water - atoms, particles and all that".

K "Hmm, so how does the movement of the particles, the atoms, and so on, give rise to, or cause, friction?"

S "Oh, they all hit each other, sort of bounce off each other".

K "And that's friction when they bounce off one another?"

S "Yeah, when they - if they split, or whatever".

(and several minutes later, when explaining the presence of friction in a sliding car - card 1)

"... oh the tyres would be worn out, because all the atoms have broken up and fallen off the tyre, or wearing away".

and later,

K "Now that you've gone through (the cards) can you perhaps put into your own words now, Steve, what friction is?"

S "Um - speeding up of particles and molecules to make fire or energy - breaking up - splitting up of atoms".

(h) Friction and the world in which we live

Occasionally, during the interviews, students were asked their views on the usefulness of friction. Most students that were asked appreciated the desirable and even essential need for what a physicist would call frictional forces. Even some very young students made sensible comments in this regard.

K "What would happen if we didn't have friction?"

T "You probably wouldn't be able to stop". (F2, boy)

Also,

K "What would happen if we didn't have any (friction)?"

S "Oh, if we didn't have friction, your feet wouldn't really touch the ground properly and grip". (F2, boy)

And,

K "So friction, do we have to have it?"

S "It would be hard to live without it".

K "Okay, and are there certain situations where we don't want to have it? Where it's not such a good thing? Or must we always have friction?"

S "I think we always need it". (F3, girl)

FRICTION AND ACROSS-CONCEPTS ASPECTS OF CHILDREN'S VIEWS

In other papers in this series (e.g. FORCE No. 16, ENERGY No. 17) we have documented some general aspects of students' views. This series of interviews on friction provided an opportunity to add further examples to this list.

(a) Everyday language

Friction is not a commonly used word in the everyday language of F1 and F2 pupils. One or two of these students when first approached about whether they had heard of friction mistook the word for a similar sounding word with which they were more familiar.

"I've heard it in science - science friction". (F2, girl)

"I've seen it in the library - it was just on a card for books - friction books". (F2, girl)

Some other students had a notion of friction as "hard to do something". This view is sufficiently broad for it to be used both in an everyday social context and in a more physics context at the same time. The following excerpt is a clear example of this dual use and the apparent interchange in the use from a physical sense to a social sense by the student in the middle of the discussion without warning.

K "What happens if you take that piece of sand paper that's wrapped around the block away from the block and then try and rub? Is it easier, or is it harder?"

N "Ah, be easier".

K "Why would it be easier?"

N "Cos the wood'll be smooth".

K "Hmm, so how does that fit in with friction? What do you know about friction?"

N "Makes things easier?"

K "Hmm, friction makes things easier? Or does it make it harder?"

N "Ah, makes things harder".

K "How can we change friction? If we had a lot of friction around, how could we change it?"

N "By - ah - co-operation - and all that". (F1, boy)

The very commonly held view that friction is rubbing, as discussed in an earlier section of the paper, relates very closely to the everyday use of the word in "friction causes wear", and "friction causes heat". The close association of friction with movement, and energy therefore has some basis in the everyday use of the word.

(b) Self-centred and human-centred viewpoints

The detailed quote in the last subsection emphasises the human-centred viewpoints that some children tend to revert to frequently. A long period of discussion may focus on physical situations and inanimate objects and suddenly the student will revert to a self-centred or human-centred viewpoint.

K "If it has been raining - does that have any effect on friction?"

L "I wouldn't go down there when it's wet".

K "Why not?"

L "Get wet pants! (laughs) and you get all wet". (F2, boy)

This human-centred viewpoint can be also found with older students. The following fifth form girl had explained that friction is involved when a car slides on a road, "two forces opposing each other".

K "How do you know friction is there?"

D "It's just what I remember".

K "Ah fine. So why in this case do you think that the car is sliding sideways?"

D "Um, he couldn't control the car". (F5, girl)

The different 'mental set' of a person trained in science compared to a young student is again evident in the following answers to the question "the girl here is putting some oil on the hinge, now why should she be doing that?"

The thrust of the question was immediately appreciated by a 6 form girl.

"Ah ... to create less friction between the hinge and the door". (F6, girl)

but a quite understandable and common response from younger children was,

"You oil the hinge door to stop the door squeaking". (F3, boy)

Sometimes even strong and repeated probing cannot shift the students' mental set.

K "What about when you're swimming? Is there anything in there that might slow you up or make you go faster?"

C "Yeah, when you get the stitch".

K "When you get the stitch? What about the water itself - does that have any effect?

C Oh, in the swimming pool, you might swallow some of that water".

K "You might swallow some of the water. What about the water itself, as you're swimming, say you've got your mouth shut, is that going to try and slow you up?"

C "No". (F1, boy)

(at this stage the interviewer gave up and introduced another stimulus card!)

(c) Animistic views

This particular set of interviews did not generate many examples of students attributing animal or human characteristics to non-living objects. Only one example will be quoted.

K "What is friction?"

J "It's when something moves against another thing and it might be rubbed or it might be moving, or trying to stop". (F4, girl)

(d) Reified views

Very few examples were also documented where students attributed a reality to friction which was unjustified. One such example was the following,

K "Is there any friction there? (Card No. 2: Sanding the wood)

M "Yeah, every time he sands with ... over the wood it just ... friction goes up in the block there".

K "Say we put some oil on that plank, would it make any difference to the friction?"

M "Oh, it won't come into the block as quickly as normal ... it would have to get through the oil". (F4, boy)

Sometimes the language suggests a reified view but on closer questioning this was not clearly reified. For example,

K "What happens when you use oil?"

A "It's making it move freely".

K "Quite right. What is that doing to the friction?"

A "It's taking more friction out so it's not much left".

K "Does it actually take the friction out? Is it possible to get hold of some friction to look at?

A "No, it's something on top of it that makes it". (F2, girl)

Subsequent questioning showed the student's idea was that the oil changes the nature of the surface and this was really what she meant by "taking out" the friction.

(e) Non-existence of non-observables

One had the strong impression with most students interviewed, that if there was no movement (which you can see) and no heat generated (which you can feel) then there was no friction present. Frictional forces on stationary objects, e.g. the frictional force on a block resting on a slope, just were not observable and hence, did not exist.

Many younger students undoubtedly restrict their thinking and talking to things which are observable or which can influence one of the five senses. The following extract from the beginning of a discussion with a third form boy exemplifies this,

K "I'm interested in that word friction - what can you tell me about friction?" What is friction? Tell me as much as you can".

A "Friction - um".

K "Where do we find friction?"

A "I don't know".

K "It's a new word for you, is it? You haven't seen it before?"

A "No, you know, I've seen it before, but I - we sort of studied it last year".

K "How did you study it? What sort of things did you cover?"

A "Oh, we done with - um - we put a whole lot of um - sort of little tiny balls on the floor and - um - rolled a duster along them, and see how far that went, and then we tried it without the balls. And that and - um".

K "So how does that link in with friction? What did that tell you about friction?"

A "Well, ah, the round balls make it go further because they're round and they can roll along underneath the duster. And when you're just doing it straight on to the lino, it doesn't go very far".

K "So what does that tell you about friction, itself? What is friction?"

A "Oh -."

K "I've got some cards here which will help. Just listening to you telling me about that example there with the balls, there's one here which I'll just find, which ties in a little bit with what you're saying. Not exactly, but pretty close. Here we are - that chap there is pushing, I suppose you call them two dusters, X and Y, on a table. He's given them both the same push and they are both identical, but one has only gone as far as there, the X, and Y has gone further. Can you explain why that could be?"

A "Well he could have something underneath that Y duster, and nothing underneath the X duster".

K "Hmm, and that something would be what?"

A "Well, as I said, some round balls".

K "Okay, so any other reason that you might be able to come up with?"

A "Oh, that side of the table might be smoother, could have a little bit of wax on it".

K "So how does the wax make a difference?"

A "Well was is, sort of, slippery".

K What about the word friction? Can we use the word friction anywhere?"

A "Ah (pauses)".

FURTHER INFORMATION AND COMMENT

The work detailed here on friction brings out a number of points. Firstly, friction is closely associated, for many students, with two surfaces rubbing together. This, in the student's mind, associates friction with heat and movement. The relationship between friction and movement is interesting in that we have earlier identified that students also closely associated force and movement (see Working Paper on Force, No. 16; and Appendix 4 of this paper).

In the minds of some students friction is a form of energy, while for other students friction occurs between only solid surfaces and there is no friction in situations involving liquids or gases. Many students have difficulty distinguishing between reaction and frictional forces, while some do not clearly distinguish between magnetic, electrical and frictional forces.

Frictional forces are perhaps difficult to understand and in our quest for teaching the idealized principles of physics, e.g. principles which hold true if friction is neglected, we have increasingly tended not to explicitly teach about frictional forces.

Questions we might ask are

(a) does that lack of teaching and learning about the scientists' view of friction make it difficult for students to understand some of the basic ideas in physics?

(b) does the lack of understanding about friction make it difficult for students to see the relationships between some of the principles and the real world in which they live?

Perhaps the common question asked in physics problem solving could be reconsidered from the point of view of teaching;

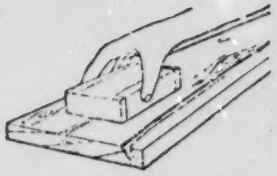
"Can we ignore friction?"

ACKNOWLEDGEMENTS

We would like to thank all those pupils who so cheerfully gave us their time, those teachers who allowed us to interview their pupils, and those teachers who administered the survey. We would also like to thank Peter Freyberg and Ross Tasker for their comments on an earlier draft of this paper.

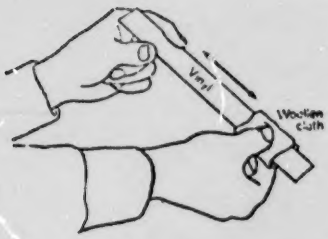
APPENDIX 1: FRICTION INTERVIEW STIMULUS CARDS

(1)



(2)

(3)



(4)

(5)

(6)

(7)

(8)

(9)

(10)

A PHYSICISTS' VIEW OF FRICTION WITH RESPECT TO THE CARDS

(1) The car is sliding sideways, so there is friction between the car and the road. The more quickly the car stops sliding the greater must have been the frictional forces against the direction in which the car was sliding or tending to slide.

(2) There is a frictional force between the sandpaper and the wood. The frictional force on the block will be in the opposite direction to the way it is being pushed.

(3) The oiling of the door hinge reduces the friction at the hinge pivots.

(4) There would be a frictional force between the vinyl and the cloth. The frictional force on the cloth will be in the opposite direction to the way it is being pushed. The sliding of one surface over the other (rubbing) separates electrical charges, so that the vinyl and cloth become oppositely charged.

(5) While a lack of friction has caused the left leg to slip, the right foot does not slip, as any tendency of that foot to move is opposed by frictional forces. Provided the foot doesn't slip, the frictional forces will always be equal, and opposite, to the horizontal forces applied to the foot by the man.

(6) There are frictional forces between the two pieces of wood. The relative movement between the pieces of wood, against those frictional forces, means the work is being done. Energy is being transferred from the man to internal energy at the wood - wood interface: the wood gets hot.

(7) There are frictional forces between the child and the slide. For a particular child the more he holds on, or drags his feet etc., the greater the frictional forces. If the child holds on, or otherwise stops, the frictional forces are maximum.

(8) There are frictional forces between the surfaces of the person and the water. These forces make it difficult for the person to move quickly through the water.

(9) If both blocks are given the same initial impulse and they are of identical mass there must be greater frictional forces, in the opposite direction to the direction of motion, on block X.

(10) There will be frictional forces on the skydivers. Once their speed reaches what is known as terminal velocity they will fall at a steady speed. When this is occuring the frictional forces upwards are equal and opposite to the gravitational forces downward.

APPENDIX 2: How does rubbing make electricity?

Some views on this topic, as elaborated in discussion about CARD 4, are detailed.

K "That, there, is like one of those plastic rulers being rubbed with a piece of cloth - or I could rub my pen on my jersey. What happens?

C "Electricity comes".

K "How do you know that?"

C "Cos it makes it real hot and it picks up paper".

K "Makes it real hot? Aha, would it still work if it didn't get hot?"

C "No".

(F1, boy)

M "Um you get synthetic electricity".

K "You get synthetic electricity? (Yes) What is that exactly?"

M "Ah, it's kind of - it's an artificial electricity that you make, sort of, by rubbing something".

K "Why do you call it artificial?"

M "Cos it's man-made, I suppose".

K "Okay, so how is it made? What causes it to be made?"

M "Heat".

(F3, girl)

C "The rubbing against it would make electricity ..."

K "So how's this electricity formed?"

C "Um - friction causing the electricity by rubbing against each other and giving off particles".

K "What's giving off particles?"

C "The cloth and the vinyl rubbing against each other, when they're causing the heat and making the electricity".

K "What are these actual particles? (Pause) Are they bits of cloth? Are they bits of vinyl? Or what are they?"

C "Um - oh, I don't know. Might be the cloth rubbing against the vinyl, both of them mixing together".

K "So is that electricity? What is the electricity made of? What is it?"

C "Um, it's the current that's coming off it. The electrical current coming off it".

K "What does this current look like? I mean, what is the current made of?"

C "Oh, it's all these atoms and molecules moving along in the same line, and making power and stuff like that".

(F4, boy)

R "... if you rub (a comb) ... onto some woollen material, not acrylic, it lifts up paper, and particles of paper torn up".

K "So how does friction do that? What actually gives it that lifting power?"

R "The molecules in the comb rub together and move around and they generate a kind of heat which lifts them up somehow ... some of them come off on to the other piece of paper and then, the comb, that's lost all the molecules, tries to regain them by lifting up the piece of paper".

(F3, boy)

K "How is this charge, in fact, brought about? How does friction cause it?"

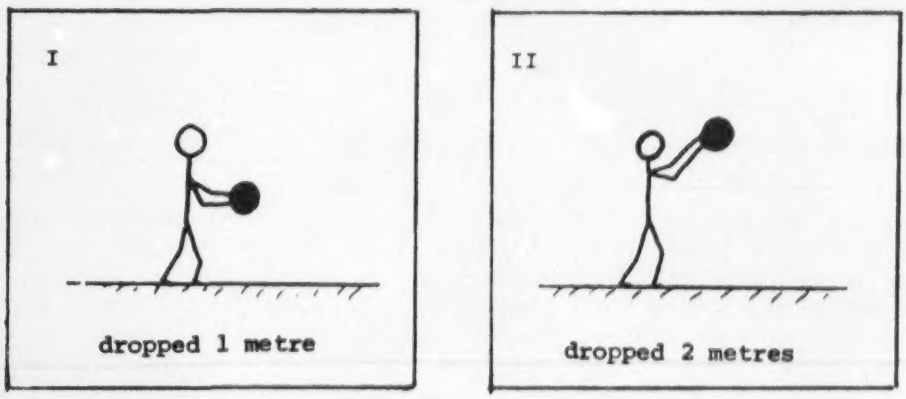
I "Um - I don't know really - um - other than the different materials. Like we were given the examples of perspex and alkathene and that. Their particles, when heated ... will react differently to become negatively or positively charged. I think that's basically the idea we were given and the teachers took it that we knew it. It was form two and three, that we were given the example and just the heat caused the two different materials to become charged when an amount of friction was introduced".

(F5, boy)

APPENDIX 3: Survey questions used to gain an indication of the prevalence of specific ideas.[8]

(a) Confusion between reaction and friction forces.

A ball is dropped from different heights onto concrete.



The ball drops straight down and is not spinning. When the ball hits the concrete the friction between the ball and the concrete will be

(a) greatest in I
(b) greatest in II
(c) the same in both cases but not zero
(d) zero in both cases

RESULTS AS PERCENTAGES[9]

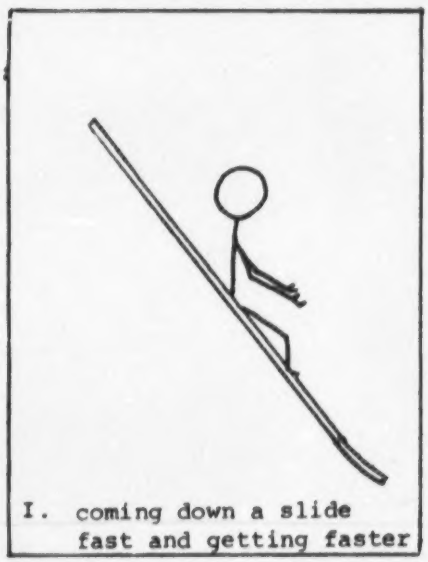
	3rd form (N = 258)	4th form (N = 200)	5th form (N = 179)	6th form (N = 147)	7th form (N = 75)
a	11	10	4	5	3
b	64	52	49	51	35
c	15	27	29	24	27
d	11	12	18	20	36

[8] The survey results were obtained from a full range of abilities in co-ed and single sex state schools (7 schools); 3-5 form students were studying Science, 6-7 form students were studying Physics. The alternative which would be the consensus view of physicists is underlined in each case.

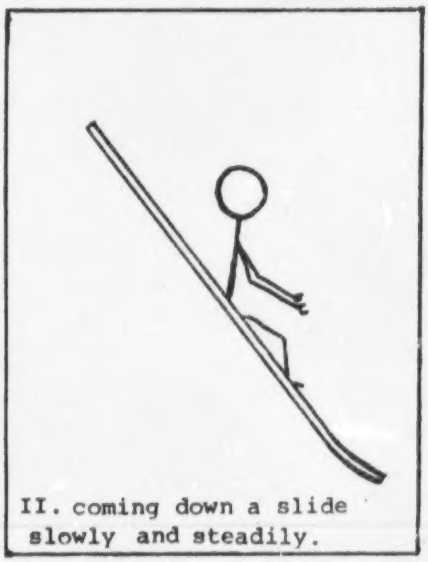
[9] Even with carefully designed questions it is impossible to be certain about the thinking which has led a student to choose a particular answer. For example a 4th former asked why he had chosen (c) above; "Well it's the law of gravity isn't it? (What is that?) Well if you drop things from different heights they hit the ground at the same time with the same speed and give out the same amount of friction".

(b) Views on friction and movement

Q.1-3 A person is playing on a slide. The pictures show what was happening at three different times. The questions are about friction between the person and the slide.



I. coming down a slide fast and getting faster



II. coming down a slide slowly and steadily.

III. not moving on the slide

Q.1. Look at picture I only. Would there be any friction?

(a) Yes
(b) No

Q.2. Look at picture II only. Would there be any friction?

(a) Yes
(b) No

Q.3. Look at picture III only. Would there be any friction?

(a) Yes
(b) No

Q.4. Look at pictures I and II only. In which of the two pictures is there more friction?

(a) More in I
(b) More in II
(c) The same in I and II
(d) There is no friction in either I or II

Q.5. Look at pictures II and III only. In which of the two pictures is there more friction?

(a) More in II
(b) More in III
(c) The same in II and III
(d) There is no friction in either II or III

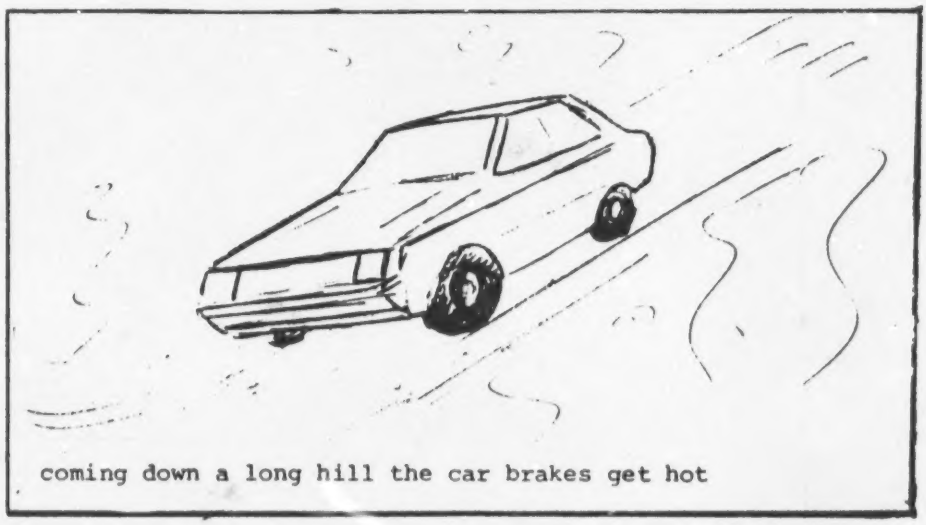
RESULTS AS PERCENTAGES

Q.1-3	3rd form (N = 252)	4th form (N = 201)	5th form (N = 179)	6th form (N = 147)	7th form (N = 74)
aab	68	71	54	36	26
abb	8	4	1	-	-
baa	8	5	3	5	5
aaa	10	15	35	56	69
bba	2	2	2	-	-
bab	4	5	5	3	-
aba	2	-	1	-	-

Q. 4	(N = 255)	(N = 201)	(N = 176)	(N = 147)	(N = 75)
a	56	53	40	24	13
b	33	35	50	66	80
c	11	11	8	10	7
d	1	1	2	-	-

Q.5	(N = 257)	(N = 201)	(N = 179)	(N = 147)	(N = 75)
a	76	81	62	44	33
b	20	15	36	52	66
c	2	5	2	4	1
d	2	-	-	-	-

(c) Friction and Energy



coming down a long hill the car brakes get hot

The energy coming out of the brakes is

(a) heat
(b) friction
(c) gravity
(d) magnetic

RESULTS AS PERCENTAGES

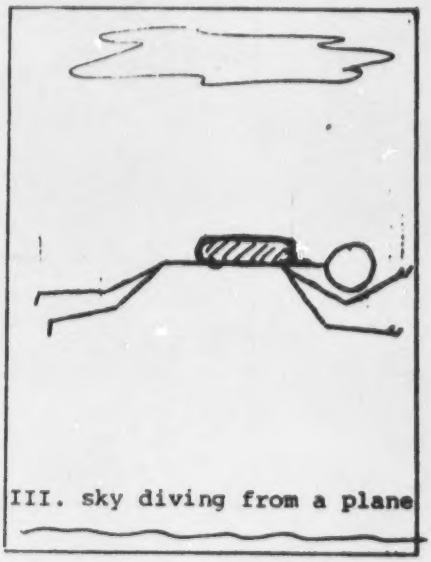
	3rd form (N = 255)	4th form (N = 198)	5th form (N = 176)	6th form (N = 147)	7th form (N = 75)
a	27	38	68	77	85
b	68	59	32	33	15
c	3	2	1	-	-
d	3	1	-	-	-

(d) Friction and Solids, Liquids and Gases

These questions are about whether there is any friction on the person.

I. coming down a slide slowly but speeding up

II. diving in a swimming pool



III. sky diving from a plane

Q.1. Look at picture I only. Would there be any friction?

(a) Yes
(b) No

Q.2. Look at picture II only. Would there be any friction?

(a) Yes
(b) No

Q.3. Look at picture III only. Would there be any friction?

(a) Yes
(b) No

RESULTS AS PERCENTAGES

Q.1-3	3rd form (N = 255)	4th form (N = 201)	5th form (N = 177)	6th form (N = 146)	7th form (N = 75)
aab	22	17	15	10	7
abb	18	17	12	4	-
aaa	40	59	66	77	85
aba	9	3	4	2	3
baa	4	1	3	2	5
bab	1	2	1	3	-
bba	2	-	-	1	-
bbb	3	1	1	-	-

(e) Friction and electricity

combing dry hair

the comb attracts small pieces of paper

The best name for the attraction of the small pieces of paper by the comb is

(a) frictional
(b) gravity
(c) electrical
(d) magnetic

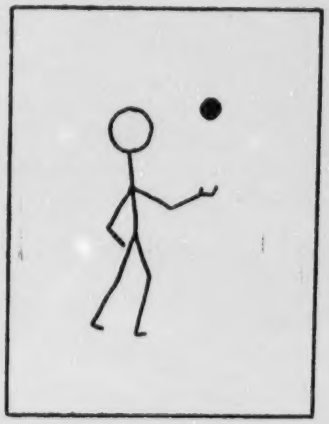
RESULTS AS PERCENTAGES

	3rd form (N = 250)	4th form (N = 200)	5th form (N = 181)	6th form (N = 147)	7th form (N = 74)
a	16	16	10	9	1
b	3	1	1	1	-
c	59	61	71	82	96
d	22	22	18	9	3

APPENDIX 4: The Association between force and movement, a quantitative analysis following the work of Zylbersztajn and Watts.[8]

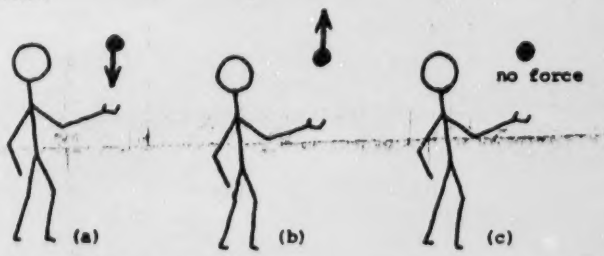
Q 1-3 A person throws a tennis ball straight up into the air just a small way.

The questions are about the total force on the ball.

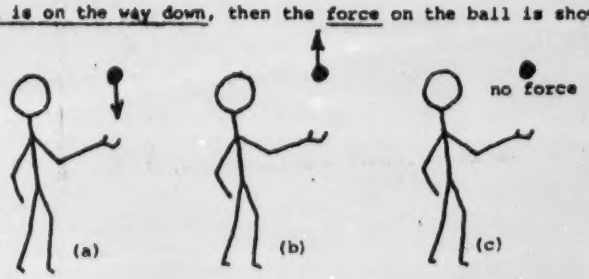


Q.1. If the ball is on the way up, then the force on the ball is shown by which arrow?

Q.2. If the ball is just at the top of its flight, then the force on the ball is shown by which arrow?



Q.3. If the ball is on the way down, then the force on the ball is shown by which arrow?



[8] Zylbersztajn, A. and Watts, D.M. Surveying Some Ideas about Force - A Pilot Study, IET, University of Surrey, 1980.

RESULTS AS PERCENTAGES

Q.1-3	3rd form (N = 254)	4th form (N = 195)	5th form (N = 174)	6th form (N = 147)	7th form (N = 75)
bca	46	53	66	53	52
baa	14	11	9	4	1
bba	4	1	1	-	-
aaa	5	11	6	22	19
aca	9	5	5	14	21
acb	11	10	10	7	7
(other)	11	9	3	-	-